

REMARKS

Applicants acknowledge receipt of the Office Action dated July 8, 2003, in which the Examiner rejected all pending claims as obvious in view of Schweitzer et al in view of Clark et al and further in view of Eri et al.

On Thursday, October 30, 2003, the undersigned and inventor Dr. Rafael Espinoza, conducted a personal interview with the Examiner and Applicants thank the Examiner for the opportunity to discuss the merits of the invention. During the interview, Applicants discussed the important distinction of liquid Peclet Number from gas Peclet Number in a Slurry Bubble Reactor, which included a simple demonstration. The demonstration was made possible using a simple toy that provided air bubbles into the bottom of a water-filled column having small plastic objects of varying density in the water. In operation, the air bubbles progressed directly up the column without any observable back-mixing while the plastic objects were clearly moving up and down and around the inside of the column. The plastic objects were revealing the back-mixing in the water. As Peclet Number is measure of whether and to what degree there is back-mixing in a reactor system, the demonstration provided clear proof that the Peclet Number for a liquid in a reactor is unlikely to be the same as the Peclet Number for the gas in that reactor.

Turning now to the present invention, Applicants have improved the productivity of a three-phase catalytic system by creating conditions in the reactor such that the gas Peclet Number is less than 0.175. Not only is operating a three-phase reactor at such a low gas Peclet Number not known in the art, but all prior art teaches away from operating such a reactor at such conditions. As the prior art does not disclose or teach the invention as claimed Applicants respectfully traverse the rejections.

Schweitzer does not suggest the use of a gas Peclet number Pe_g less than 0.175

The Examiner quotes paragraph [0018] of Schweitzer, which reads:

“...Peclet numbers for the gas phase of more than 10, also known as ‘gas Peclet numbers or Pe_g ’, lead to a plug flow type operation regarding the gas phase, while gas Peclet numbers (Pe_g) of less than 1 correspond to systems in which the gas phase is perfectly mixed or stirred. Ideal perfectly stirred systems correspond to Peclet numbers tending towards zero. This Peclet number is equal to $Pe_g = H u_g / D_{ax}$, where H is the expansion height of the catalytic bed, u_g is the space velocity of the gas and D_{ax} is the axial dispersion coefficient of the gas phase.”

The statements in paragraph [0018] are true statements, but they are merely physical truths about the meaning of Peclet Numbers and do not disclose the present invention. The Examiner also mentions, but does not quote, paragraph [0019] of Schweitzer, which reads:

“The method that can produce an optimal slurry bubble column that is described in Ep-B-0 450 860 comprises injecting gas at a mean superficial velocity such that the formation of slug flow is avoided, the gas superficial velocity being $0.2 (H/D_{ax})$ [*sic*] or more. A further condition applies to the superficial velocity of the liquid and the sedimentation rate of the solid (generally the catalyst) so that the solid is suitably fluidised in the liquid phase.”

Applicants would like to call to the Examiner’s attention the fact that paragraph [0019] in the Schweitzer reference contains a typographical error, inasmuch as the reference EP-B-0 450 860 actually teaches that the superficial gas velocity should be “ $U_g = 0.2D/H$ ”, not “ $0.2 (H/D_{ax})$ ” as it appears in paragraph [0019]. This is an important point, because the teaching of the EP’860 reference, as affirmed by Schweitzer, is that the gas Peclet number Pe_g should be greater than 0.2 to avoid significant backmixing.

To further illustrate this point, Applicants would point out that the EP’860 reference (and its counterpart, U.S. Patent No. 4,348,982) explicitly state that, “Optimum performance of slurry bubble column reactors requires adequate fluidization of the catalyst particles while minimizing backmixing of the reactants in the gas phase.” (EP’860, page 4, line 15). Again, the optimal method is disclosed as “injecting the gas phase into a column...with and appropriate velocity so that the solid phase is fluidized while still maintaining ‘plug flow’ reactor behavior over the column length.” (EP’860 page 5, line 25).

Clearly, the EP’860 reference and Schweitzer are only describing the state of the art for this type of reactor. More specifically, it was known that low Peclet numbers (for liquid or gas) correspond to more back-mixing (for the liquid or gas, respectively) and that high Peclet numbers are associated with plug flow, and it was believed and understood that the optimal method for operating such a column comprised *adjusting the gas flow rate (velocity) such that the gas Peclet number Pe_g was greater than 0.2.*

In addition, Schweitzer also teaches that the liquid Peclet number, Pe_L , should be between 0.03 and 1, again emphasizing the importance of plug flow behavior. This is important because, while the gas Peclet Pe_g number is solely a function of the gas superficial velocity, the liquid Peclet number Pe_L is a function of both the gas superficial velocity U_g (or “ u_g ”) and the liquid superficial velocity U_L .

To illustrate this relationship, Applicants have attached three plots as Exhibit “A.” Each plot illustrates, for a different reactor configuration, the relationship between gas Peclet numbers and liquid Peclet numbers at various liquid velocities. It can be seen that when the gas superficial velocity is in a range that achieves a liquid Peclet number of “at least 0.03,” i.e. toward the left side of each plot, the gas Peclet number is much higher than the liquid Peclet number. This is because, as demonstrated and discussed, the gas phase switches from well-mixed to plug flow at a much lower velocity than the liquid. Put another way, in order to achieve a “high” liquid Peclet number and thereby minimize liquid backmixing, one is forced to concurrently accept a high gas Peclet number.

Applicants’ claimed invention is surprising in view of the references

In the context of this understanding of the ideal reactor conditions, namely that plug flow in the gas phase is required for optimal operations, Applicants discovered, surprisingly and contrary to the teachings of the art, that productivity of the system could *nonetheless* be increased by operating with a highly mixed gas phase. As set out in the present specification, this was described as a gas Peclet number less than 0.175.

The present invention is directly contrary to the teachings of the references and to the understanding that existed in the state of the art prior to the invention.

Applicants have discovered that when the gas superficial velocity is sufficiently elevated, significant cost advantages can be realized. As illustrated in the Table attached to Exhibit “B” and reproduced for the Examiner’s convenience below, the productivity of a hypothetical but plausible system, measured in gHC/kg.cat/hr, can be increased by about 30% when the gas velocity is increased from a velocity that is low enough to ensure operation within the *plug flow liquid* regime to velocities that are high enough to provide a *well-mixed gas* regime. By way of example and referring still to the Table: for a constant liquid velocity of 1.5 cm/s, in order to obtain a liquid Peclet number (third row) of at least 0.03 (column 2) the gas superficial velocity (first row) has to be less than 20 cm/s (column 3). To achieve higher liquid Peclet numbers, it is necessary to use even *lower* gas velocities. By contrast, Applicants have discovered that better results are obtained when the gas velocity is *increased* (columns 4-8).

Applicants discovery of better economics would have been counterintuitive to those skilled in the art prior to Applicants invention as the focus was on high conversion of the reactants and not

on high productivity of products by a reactor. In other words, it was generally understood that getting a high percentage of the reactants converted to products was a primary driver for profit, but it turns out that getting a lower percentage of reactants converted where a much larger amount of reactants move into and through the reactor can actually provide a greater economic return. The greater economic return comes from operating the reactor at gas Peclet Numbers of less than 0.175.

Hypothetical Productivities (gHC/kgcat/hr) for Various Gas Velocities;
at 215°C, 400 psig, fixed catalyst loading, and intrinsic activity

		1	2	3	4	5	6	7	8
1	Gas superficial velocity, cm/s	10	15	20	25	30	35	40	45
2	Liquid superficial velocity, cm/s	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
3	Liquid Peclet number	0.042	0.033	0.028	0.026	0.024	0.022	0.021	0.020
4	Gas Peclet number	0.31	0.19	0.15	0.11	0.09	0.07	0.06	0.05
5	Productivity, gHC/kgcat/hr	210	301	354	377	386	389	391	392

Because Schweitzer does not teach or suggest the use of a gas Peclet number less than 0.175 and because operating with such high gas velocities is not obvious in view of Schweitzer and the rest of the references, Applicants respectfully submit that the claims as amended are allowable over the art.

Neither Clark et al and Eri et al teach what Schweitzer lacks

Clark et al. is cited by the Examiner to show productivity of a Fisher Tropsch reactor system being in the range of what was claimed. Clark does not make disclose or describe gas Peclet Numbers in the range claimed or described well mixed gas in a three phase reactor. As such, Clark et al. is irrelevant to the patentability of the present invention.

Eri et al. is cited to show high superficial gas velocity in an FT reactor. However, the invention in Eri et al. is focused on higher activity catalyst materials and to the extent it describes a reactor system for carrying out the reaction, it broadly describes all possible reactor systems including fixed bed, fluidized bed, ebulliating bed and slurry. There is no mention of Peclet Number for either liquid or gas or any indication or preference for how well mixed a slurry would be in slurry reactor. As such, Eri et al. clearly has no bearing on the essential aspects of the present invention as claimed.

Amendment to Claims 1

Applicants have amended claim 1 to delete the requirement that the single pass conversion be between 35 % and 75 %. This is because, upon further consideration, Applicants believe that the recitation requiring the gas Peclet number to be less than 0.175 is sufficient to distinguish the claims from the teachings of the prior art.

Affidavit

In further support of the assertions made herein, Applicants submit an Affidavit of Rafael Espinoza, who is an inventor in the present case. Dr. Espinoza confirms that the use of gas Peclet numbers less than 0.175 was non-obvious in the state of the art for three-phase Fischer-Tropsch reactors at the time the present invention was made. Dr. Espinoza's Affidavit is attached hereto as Exhibit "B."

New Claims

To more explicitly claim the surprising results made possible by the present claims, new dependent claims have been added, which claim that the volume productivity of the catalytic system is at least 350 gHC/kg.cat/hr. Because they depend from allowable base claims, and because nothing in the art teaches or suggests a reactor system meeting any of these limitations, these new claims should also be allowable.

Information Disclosure Statement

Applicants are submitting concurrently herewith an Information Disclosure Statement containing additional references collected by the Applicant since filing the previous Information Disclosure Statement.

Conclusion

Applicants again thank the Examiner for the opportunity to discuss the subject matter of the present case in the interview. Applicants respectfully submit that the present amendments and arguments place the claims in condition for allowance and therefore request that the rejection be withdrawn and the claims allowed. If the Examiner has any questions regarding the foregoing, he is invited to telephone the undersigned at (713) 238-8043.

Respectfully submitted,

A handwritten signature in black ink, appearing to read "Marcella D. Watkins", written over a horizontal line.

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